

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority of Japanese Patent Application No. 2000-180933, filed in Japan on June 16, 2000, the entire contents of which are hereby incorporated herein by reference.

### **BACKGROUND OF THE INVENTION**

#### **1. Field of the invention:**

[0002] The present invention relates to a high frequency sputtering device, and in particular to a high frequency sputtering device having a grounding shield which is arranged at the circumference of the target.

#### **2. Description of Related Art:**

[0003] In the field of semiconductor devices, there is increasing integration and miniaturization of the elements. In order to respond to this, semiconductor manufacturing processes are carried out using high frequency sputtering devices for such operations as filling film inside minute holes. Figure 10 is a sectional front view of a conventional high frequency sputtering device. A circular cathode 14 is mounted at the mouth of the upper part of a processing chamber 10 by means of an insulator 12. An interface device 16, filter 18 and high frequency power supply 20 are connected in series with this cathode 14. A target 22 is mounted on the lower face of the cathode 14. A cylindrical grounding shield 24 is mounted on the processing chamber 10 in such a way that it surrounds the cathode 14 and the target 22. As shown in a magnified view in Figure 11, the gap between the grounding shield 24 and the cathode 14 is narrow, being approximately 2 mm. The size of this gap is sufficiently smaller than the sheath thickness necessary to support plasma, in order to prevent plasma from entering the gap. The substrate holder 26 is arranged inside the processing chamber 10 so as to be opposite the target 22. A substrate 28 is mounted on this substrate holder 26.

[0004] The operation of this high frequency sputtering device will now be explained. Plasma is generated between the target 22 and the substrate 28 when the processing chamber 10 is exhausted by means of an exhaust device 32, electric discharge gas is introduced from a gas feeder in device 30 and high frequency electric power is applied to the cathode 14. Ions in this plasma are sputtered on to the target 22, particles of the target 22 are scattered, and these particles adhere to the surface of the substrate 28, so that a thin film is deposited on the surface of the substrate 28. The high frequency generally used in the high frequency power supply 20 is 13.56 MHZ.

[0005] In the conventional device in Figure 10, because the gap between the grounding shield 24 on the one hand and the cathode 14 and target 22 on the other is narrow and long, large stray capacitances are generated in this gap part. The problem occurs that some of the high frequency electric current supplied from the high frequency power supply 20 flows into this stray capacitance and high frequency electric current is lost. This problem becomes particularly acute at high frequencies.

[0006] For this reason, a high frequency sputtering device in which the grounding shield is reticulate and the stray capacitance is small has been designed. See Japanese Patent No. 2832360. However, further problems arise with a reticulate grounding shield, such as the fact that its configuration is fragile and abnormal electric discharges are generated at the reticulate shield.

[0007] In addition, techniques are known in which the stray capacitance is reduced by laminating a plurality of metal plates on the rear surface of the electrode in order to reduce the loss of high frequency current in a CVD device (plasma CVD device) which uses plasma excited by high frequency waves. See Japanese Laid-Open Application No. S59-63775. However, this reference makes no mention of measures for reducing the stray capacitance when a grounding shield is provided at the circumference of the electrode. In the sputtering device

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there is the problem that, in order to prevent particles discharged from the target from adhering to the inner wall of the device, becoming detached, dropping down and forming particulates which contaminate the substrate, a grounding shield is provided in order to cover the end part of the target, and a large stray capacitance is generated between this grounding shield and the target. In the above-mentioned plasma CVD device, because only the stray capacitance of the rear face of the electrode is reduced, even if a sputtering device of such a configuration is used it is not possible to reduce the stray capacitance between the grounding shield and the target and the problem of the loss of high frequency current cannot be solved.

#### **OBJECTS AND SUMMARY**

[0008] The present invention is aimed at solving the above-mentioned problems and one of its objects is to provide a high frequency sputtering device which can prevent the loss of high frequency current due to stray capacitance, but which does not have a fragile configuration and in which abnormal electric discharges are not generated.

[0009] In one embodiment of a high frequency sputtering device according to the present invention, an annular dielectric member is in contact with an outer circumferential face of a cathode. A projecting part of the dielectric member projects further toward the target than the target mounting face of the cathode. An annular metal member is mounted on the projecting part and the metal member is formed in such a way that it preferably projects 3 mm or more further inward than the inner circumferential face of the projecting part of the dielectric member. The minimum distance between the metal member and the target is preferably made 3 mm or less. By employing such a configuration, the stray capacitance between the cathode and target on the one hand and the grounding member on the other is reduced and the loss of high frequency current is reduced. Moreover the configuration is not fragile and abnormal electric discharges are not generated.

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**[0011]** The metal members can also be grounded (in other words placed in contact with the processing chamber) or it can be electrically insulated from the processing chamber. In addition, it is desirable to make these metal members from the same material as the target. If they are made from the same material, even if the metal members are sputtered and sputter particles from the metal members become mixed into the thin film formed on the substrate, this does not cause contamination of the thin film.

**[0012]** A plurality of metal members can be provided. In such cases, it is desirable to bend the gap between the metal members in such a way that it is not possible to look through from the mouth part of the gap to the surface of the dielectric member. As a result, even if sputter particles penetrate the interior of the gap from the mouth part of the gap, the sputter particles cannot reach the surface of the dielectric member because they travel in a straight line. Therefore, it is possible to prevent a situation in which a film is deposited on the surface of the dielectric member and the metallic members short-circuited to one another.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0013] Figure 1 is a sectional front view of a first embodiment of the present invention.

[0014] Figure 2 is an oblique, partially broken-open view of a dielectric ring and metal ring of the sputtering device according to Figure 1.

[0015] Figure 3 is a magnified sectional front view of a section through the dielectric ring and metal ring of the sputtering device according to Figure 1.

[0016] Figure 4 is a sectional view of a second embodiment of the present invention, as in Figure 3.

[0017] Figure 5 is a sectional view of a third embodiment of the present invention, as in Figure 3.

[0018] Figure 6 is a sectional view of a fourth embodiment of the present invention, as in Figure 3.

[0019] Figure 7 is a sectional view of a fifth embodiment of the present invention, as in Figure 3.

[0020] Figure 8 is shows a sectional view of a sixth embodiment of the present invention, as in Figure 3.

[0021] Figure 9 is a sectional view of a seventh embodiment of the present invention, as in Figure 3.

[0022] Figure 10 is a sectional front view of a conventional high frequency sputtering device.

[0023] Figure 11 is a magnified sectional front view showing a section through the dielectric ring and metal ring of the sputtering device according to Figure 10.

### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[0024] Embodiments of the present invention are explained below with reference to the Figures. The first embodiment of the present invention is shown in a sectional front view. A shaft 40 of a cathode 38 is mounted on an upper part of a

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processing chamber 34 by means of an insulator 36. An interface device 42, a filter 44 and a high frequency power supply 46 are connected in series with the shaft 40. A target 48 is mounted on the lower face of the cathode 38. An inner circumferential face of an annular dielectric ring 50 is placed in contact with an outer circumferential face of the circular cathode 38. An outer circumferential face of the dielectric ring 50 is in contact with the inner face of the side wall (cylindrical) of the processing chamber 34. A hollow circular plate-shaped metal ring 52 is mounted on a lower face of the dielectric ring 50. The dielectric ring 50 and the metal ring 52 will be explained in detail later. A substrate holder 54 is arranged inside the processing chamber 34 in such a way that it faces the target 48. A substrate 56 is mounted on this substrate holder 54. The processing chamber 34 is at ground potential. In this embodiment, the substrate holder 54 is also at ground potential.

[0025] The operation of this high frequency sputtering device will now be explained. Plasma is generated between the target 48 and the substrate 56 when the processing chamber 34 is exhausted by means of an exhaust device 58, electric discharge gas is introduced from a gas feeder device 60 and a high frequency current is applied to the cathode 38. Ions in this plasma sputter onto the target 48, particles from the target 48 are dispersed, and these particles adhere to the surface of the substrate 56, so that a thin film is deposited on the surface of the substrate 56. In this embodiment, the frequency of the high frequency power supply 46 is 13.56 MHZ.

[0026] Figure 2 is an oblique, broken-open view of the dielectric ring 50 and the metal ring 52. As shown in Figure 2, the dielectric ring 50 and the metal ring 52 are circular and are integrally coupled. The material of the dielectric ring 50 is, for example, polytetrafluoroethylene, quartz, aluminum oxide, or the like.

[0027] Figure 3 is a magnified sectional front view showing the vicinity of a section through the dielectric ring 50 and the metal ring 52. The inner

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circumferential face of the dielectric ring 50 is in contact with the outer circumferential face of the cathode 38. The dielectric ring 50 projects downward by a distance "a" from the lower face of the cathode 38. This part of the dielectric ring 50 extending below the lower face of the cathode 38 is referred to as the projecting part of the dielectric ring 50. The hollow circular plate-shaped metal ring 52 is mounted on the lower face of this projecting part. The metal ring 52 is 3 mm thick, although other thicknesses may be used. The metal ring 52 is arranged parallel with the surface of the target 48. The distance between the upper face of the metal ring 52 and the lower face of the cathode 38 is the same as "a". The inner circumferential edge 64 of the metal ring 52 projects inward by a distance "b" from the inner circumferential face 62 of the dielectric ring 50. Because the metal ring 52 projects inward from the dielectric ring 50 in this way, it becomes difficult for film to be deposited on the inner circumferential face 62 of the dielectric ring 50. The inner circumferential edge 64 of the metal ring 52 is spaced apart from the outer circumferential face of the target 48 by a distance "c". The outer circumferential edge of the metal ring 52 is in contact with the inner face of the side wall of the processing chamber 34. In this embodiment,  $a = 2.5$  mm,  $b = 3$  mm and  $c = 2.5$  mm, although other distances may also be used. Therefore, the gap between the metal ring 52 on the one hand and the cathode 38 and target 48 on the other is 2.5 mm (distance c and distance a). In addition, the depth of the gap, which is the shortest path extending from the entrance of the gap to the inner circumferential face 62, is the sum total of the thickness of the metal ring 52 (3 mm) and the length by which the metal ring projects ( $b = 3$  mm), and is approximately 6 mm. In this way, because the gap is 3 mm, or less, and the depth of the gap is 3 mm, or more, plasma does not enter the gap. Consequently, film is not deposited on the inner circumferential face of the projecting part of the dielectric ring 50, and the cathode 38 and target 48 do

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not short-circuit to the metal ring 52 (in other words there is no short-circuiting to the processing chamber 34).

[0028] If the configuration of Figure 3 is compared with the configuration of the device in Figure 11, in the configuration of the device in Figure 11, the cylindrical grounding shield 24 is mounted so as to surround the cylindrical cathode 14, whereas in the configuration according to Figure 3 the hollow circular plate-shaped metal ring 52 which is parallel with the surface of the target 48 is merely mounted so as to surround the vicinity of the outer circumference of the target 48.

Therefore compared to the configuration according to the device in Figure 11, in the configuration according to Figure 3 the stray capacitance between the metal ring 52 (performing the function of the grounding shield) and the target 48 becomes extremely small. Therefore, the loss of high frequency electric current is reduced.

[0029] In the configuration according to Figure 3, the present invention employs a configuration comprising a dielectric ring 50 and metal ring 52, instead of the conventional grounding shield, in order to reduce the stray capacitance between the cathode 38 and the grounding shield. In this context, in order to make the device efficient, it is useful to prevent the stray capacitance between the cathode 38 and processing chamber 34 from becoming large in other components. Therefore, it is desirable to configure the distance between the cathode 38 and the parts of the processing chamber 34 generally as follows. Firstly, it is preferable for the distance L2 between the outer circumferential face of the shaft 40 of the cathode 38 and the inner circumferential face of the mouth part of the top plate of the processing chamber 34 to be made 5 mm or more, and for the distance H3 in the height direction of the gap part of this distance L2 to be made 150 mm or less. In addition, it is preferable for the distance H1 between the upper face of the cathode 38 and the lower face of the top plate of the processing chamber 34 to be made 20 mm or more, for the distance L1 between the outer circumferential face of the

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cathode 38 and the inner face of the side wall of the processing chamber 34 to be made 20 mm or more, and for the distance H2 in the height direction of the gap part of this distance L1 to be made 50 mm or less. However, other distances may suffice depending upon other factors including the frequency and power levels used.

[0030] When the stray capacitance generated when high frequency electric power is applied to the cathode 38 and target 48 configured as shown in Figure 3 is tested, the following occurs. If the radius R1 of the shaft 40 of the cathode 38 is made 20 mm, the radius R2 of the cathode 38 is made 140 mm, the distance L1 to the inner face of the side wall of the processing chamber 34 from the outer circumferential face of the cathode 38 is made 20 mm, the distance H1 to the upper face of the cathode 38 from the lower face of the top plate of the processing chamber 34 is made 20 mm, the thickness H2 of the cathode 38 made 50 mm, and the dimensions relating to the gap are as mentioned above  $a = 2.5$  mm,  $b = 3$  mm,  $c = 2.5$  mm, then the stray capacitance between the cathode 38 and target 48 on the one hand and the grounding potential (processing chamber 34 and metal ring 52) on the other is approximately 4-5 pF when the high frequency is 13.56 MHZ.

[0031] In contrast with this, in the configuration according to Figure 11, when the dimensions of the cathode 14 are made approximately the same as in Figure 3, the stray capacitance between the cathode 14 and target 22 on the one hand and the grounding potential (processing chamber 10 and ground shield 24) on the other rises drastically to about 10,000 pF.

[0032] It should be noted that in the configuration according to Figure 3, when the aim is just to reduce the stray capacitance, the stray capacitance is reduced more when the dielectric ring 50 is not present (because the dielectric constant of the dielectric is greater than the dielectric constant of a vacuum), but it is not preferable to remove the dielectric ring 50 because then there would be the risk of

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**[0035]** In this embodiment also, because the gap between the target 148 and the metal ring 166 is 3 mm or less and the depth of the gap is 3 mm or more, plasma does not enter the gap. Consequently, film is not deposited on the inner

circumferential face of the dielectric ring 165, and the cathode 138 and metal ring 166 do not short-circuit. In addition, because the gap between the metal rings 166, 168, 170 is narrow, being only 2.5 mm, plasma is not generated in the gap, and the metal rings are not sputtered by plasma. Therefore, film is not deposited on the inner circumferential face (the inner circumferential face which is exposed to the gap between the metal rings) as a result of such sputtering. Consequently, the metal rings 166, 168, 170 do not short-circuit one another and there is no risk of the stray capacitance increasing.

[0036] In this embodiment, because the three metal rings 166, 168, 170 are arranged in parallel leaving spaces between them, the stray capacitance is less than when one ring is arranged. This point will now be explained. If the stray capacitance between the target 148 and the lower metal ring 170 (grounded) is C, the stray capacitance between the target 148 and the upper metal ring 166 is  $C_1$ , the stray capacitance between the upper metal ring 166 and the central metal ring 168 is  $C_2$ , and the stray capacitance between the central metal ring 168 and the lower metal ring 170 is  $C_3$ , the following formula is obtained.

$$1/C = 1/C_1 + 1/C_2 + 1/C_3$$

Therefore, the greater the number of laminated metal rings, the greater the overall reduction in stray capacitance C.

[0037] Figure 5 shows a sectional view of a third embodiment of the present invention, as in Figure 3. In this embodiment, six metal rings 272, 274, 276, 278, 280, 282 are mounted concentrically in the vicinity of the upper face of the dielectric ring 271. The innermost metal ring 272 has an L-shaped section. This metal ring 272 is composed of a hollow circular plate-shaped horizontal part 273 which is parallel with the surface of the target 248 and of a cylindrical vertical part 275 which is perpendicular to the horizontal part 273. The inner circumferential edge of the horizontal part 273 projects inwardly by only 5 mm from the inner circumferential face of the dielectric ring 271. The vertical part 275 is

approximately in the same position as the inner circumferential face of the dielectric ring 271. The distance between the upper face of the horizontal part 273 and the surface of the target 248 is approximately 2 mm. Five cylindrical metal rings 274, 276, 278, 280, 282 with different diameters are arranged concentrically on the outside of the metal ring 272 with an L-shaped section. The sectional shape of these cylindrical metal rings is perpendicular to the surface of the target 248, and projects downward by only 7 mm from the lower face of the dielectric ring 271. The gap between these cylindrical metal rings is approximately 2 mm in each case. The gap between the vertical part 275 of the L-shaped metal ring 272 and the innermost cylindrical metal ring 274 is approximately 2 mm. However, alternatively, other distances may be used instead of those set forth above.

[0038] In this embodiment, the six metal rings are electrically floating because they are not in contact with the cathode 238, target 248 or the processing chamber 234. Therefore, the stray capacitance between the target 248 and the grounding member (the processing chamber 234 in this case) is determined by the capacitive series connection between the target 248, the six metal rings and the processing chamber 234.

[0039] Figure 6 is a sectional view of a fourth embodiment of the present invention, as in Figure 3. In this embodiment, three metal rings 386, 388, 390 are mounted aligned one on top of the other in the vicinity of the lower face of the dielectric ring 384. The sectional shape of these metal rings will be explained below. The upper metal ring 386 and lower metal ring 390 project inward by only 5 mm from the inner circumferential face of the dielectric ring 384. The end of the metal ring 386 is bent downward perpendicularly by only 2 mm. The end of the lower metal ring 390 is bent upward perpendicularly by only 2 mm. The lower metal ring 390 covers the lower face of the dielectric ring 384 and its outer circumferential edge is in contact with the inner face of the side wall of the processing chamber 334. The gap between the upper face of the upper metal ring

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386 and the surface of the target 348 is approximately 2 mm. The central metal ring 388 projects inward by only 10 mm from the inner circumferential face of the dielectric ring 384. The end of the metal ring 388 is extended upward and downward, and the overall sectional shape of the metal ring 388 takes on the form of a capital T. The three metal rings 386, 388, 390 are all 3 mm thick. The gaps between the upper and lower metal rings 386, 390 on the one hand and the central metal ring 388 on the other are bent at a right angle. The horizontal and vertical gaps between the end component of the central metal ring 388 and the end components of the upper and lower metal rings 386, 390 are 2 mm. In this way, by making right-angled bends in the gaps between the metal rings it becomes impossible to look through to the surface of the dielectric ring from the mouth part of the gap, with the result that even if sputter particles penetrate these gaps from the exterior, it is difficult for these sputter particles to reach the inner circumferential face of the dielectric ring 384. Therefore, compared with the embodiment in Figures 3 to 5, it is extremely difficult for film to become deposited on the inner circumferential face of the dielectric ring 384 which is exposed to the gap between the metal rings. In addition, plasma cannot enter the gap between the target 348 and the metal ring 386, or the gap between the metal rings. In this embodiment, only the lower metal ring 390 is at ground potential, and the upper metal ring 386 and the central metal ring 388 are electrically floating. However, alternatively, other distances may be used instead of those set forth above.

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[0040] Figure 7 is a sectional view of a fifth embodiment of the present invention, as in Figure 3. In this embodiment, the five metal rings 494, 496, 498, 400, 402 are mounted aligned one on top of the other in the vicinity of the upper face of a dielectric ring 492. The sectional shape of these metal rings will be explained below. The metal rings 494, 496, 400, 402, which with the exception of the central metal ring 498 are flat, project inward by only 5 mm from the inner

circumferential face of the dielectric ring 492. The lowermost metal ring 402 covers the lower face of the dielectric ring 492 and its outer circumferential edge is in contact with the inner face of the side wall of the processing chamber 434. It projects inwardly by only 10 mm from the inner circumferential face of the dielectric ring 492. The end of the metal ring 498 is extended in the upward and downward direction, and in addition the upper and lower ends are bent back in the outer radial direction. The upper bent-back part 404 covers the vicinity of the end of the uppermost metal ring 494, and the lower bent-back part 406 covers the vicinity of the end of the lowermost metal ring 402. In this way, the entire sectional shape of the central metal ring 498 is shaped like a trident. Therefore, the right-angled bent part in the gap between the central metal ring 498 and the other metal rings is formed in two portions. The vertical gap between the five metal rings is 2 mm. The horizontal gap between the inner circumferential edge of the flat metal rings 494, 496, 400, 402 and the end part of the central metal ring 498 is also 2 mm. The gap between the upper face of the upper bent-back part 404 and the surface of the target 448 is approximately 2 mm.

[0041] In this embodiment also, in the same way as in the embodiment in Figure 6, the gap between the metal rings is bent at a right-angle, and it becomes impossible to look through to the surface of the dielectric ring from the mouth part of the gap, with the result that, compared to the embodiments in Figures 3 to 5, it becomes extremely difficult for particles to pass through this gap, and it becomes extremely difficult for film to be deposited on the inner circumferential face of the dielectric ring 492 which is exposed to the gap between the metal rings. In addition, plasma cannot enter the gap between the target 448 and the metal ring 498 or the gap between the metal rings.

[0042] The foregoing distances are examples of one embodiment. Alternative embodiments using different distances may be contemplated by the present invention.

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[0043] Figure 8 is a sectional view of a sixth embodiment of the present invention, as in Figure 3. In this embodiment, three metal rings 506, 508, 510 are mounted one on top of the other leaving spaces between them, in the vicinity of the lower face of the dielectric ring 504. The sectional shape of these metal rings will be explained below. The lower face of the upper metal ring 506 and the upper face of the central metal ring 508 are given mutually complementary undulating shapes. The gap between them is 2 mm. In addition, the lower face of the central metal ring 508 and the upper face of the lower metal ring 510 are given mutually complementary undulating shapes and the gap between them is 2 mm. The distance between the upper metal ring 506 and the surface of the target 548 is 2.5 mm. The inner circumferential edge of the three metal rings 506, 508, 510 projects inward by only 6 mm from the inner circumferential face of the dielectric ring 504. The lower metal ring 510 covers the lower face of the dielectric ring 504, and its outer circumferential edge is in contact with the inner face of the side wall of the processing chamber 534. Therefore, the two metal rings 506, 508 which are the upper ring and central ring are electrically floating while only the lower metal ring 510 is at ground potential. In this embodiment, the gap between the three metal rings is given an undulating shape and it becomes impossible to look through to the surface of the dielectric ring from the mouth part of the gap, with the result that, compared with the embodiment in Figure 3, it is extremely difficult for sputter particles to pass through this gap, and it is extremely difficult for film to be deposited on the inner circumferential face of the dielectric ring 504. In addition, plasma cannot enter the gap between the target 548 and the metal ring 506 or the gap between the metal rings.

[0044] Figure 9(a) is a sectional view of a seventh embodiment of the present invention, as in Figure 3. In this embodiment, firstly the section of the dielectric ring 614 is shaped in a special way. In this dielectric ring 614, the inner circumferential face of the component which projects in a downward direction

**[0045]** Figure 9(b) is a magnified view showing the specific mounting configuration of the above-mentioned metal rings 624, 626. The metal rings 624, 626 are engaged in the plate parts 620, 622 in such a way that they surround the inner circumferential edges of the plate parts 620, 622 of the dielectric ring 614. Figure 9(c) is a magnified view showing another mounting configuration of the



**[0052]** (5) In the embodiment of the above according to the above-mentioned Figure 1, the substrate holder 54 is grounded, but it is also possible for the substrate holder 54 to be electrically insulated from the processing chamber 34, and in that case it is also possible to apply a bias voltage to the substrate holder 54.

[0053] In the high frequency sputtering device according to the present invention, the stray capacitance between the target and the grounding member and the loss of high frequency electric current are reduced in comparison with a conventional device by arranging dielectric members and metal members in a particular configuration at the circumference of the cathode and target. What is more, the configuration is not fragile and abnormal electrical discharges are not generated.

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